

## **Galaxy Microsystems, Inc.**

2127A Ringwood Avenue

San Jose, CA 95131

Telephone: (408) 894-7043

Fax: (408) 894-7045

### **Company Background**

Galaxy Microsystems, Inc. was incorporated in 1985. The company has been primarily active in the design of radio frequency (RF) systems for the military, emphasizing the use of digital gallium arsenide technology. In 1989, Galaxy was awarded a contract by the U.S. Army for development of a spread spectrum radiolocation system for training applications. This system, based on low frequency transmissions from network towers, was successfully demonstrated to the Army in 1991. Despite a successful demonstration, DoD funds for system deployment were not available. Galaxy is currently seeking to commercialize this technology.

Galaxy has offices in San Jose, California, and Austin, Texas, and has a staff of approximately 15 employees.

### **Galaxy Position/Location System**

The Galaxy Position/Location (P/L) System requires the installation of four towers on the periphery of a metropolitan coverage area. Four transmitters will cover an area of approximately 2,500 square miles. Additional transmitters can be added to increase the coverage area. The towers broadcast ground-wave signals in the LF band (180-450 KHz) using spread-spectrum Code Division Multiple Access (CDMA) modulation. Transmission power is typically 20-40 watts.

Galaxy receiver modules compute location based on Time-Difference-of-Arrival (TDOA) or phase difference of three received signals referenced to the fourth. The phase differences are used along with the known locations of the transmitters to calculate position.

A System Area Monitor is used to maintain transmitter alignment and to make transmitter phase and clock drift rate corrections as needed. When the error components of any signal exceed an established threshold, a control message is sent to the corresponding transmitter causing it to realign with the other signals.

### **Target Applications**

Applications for the Galaxy P/L system include mobile 9-1-1 location and fleet management. The system is also targeted at the vehicle navigation market, based on the

capability of the system to compute accurate location within the vehicle. Other commercial and consumer applications are also targeted.

### System Status

Following demonstration of the P/L system to the U.S. Army in 1991, a test system was installed in Austin, Texas. Field tests and demonstrations were conducted over a 9 month period. These tests were used to evaluate system software upgrades, including software to support tracking with signals from only three towers.

Galaxy reports that the next step, based on availability of funding, will be development of a pre-production configuration.

### Accuracy

Galaxy reports that field tests demonstrated typical accuracies of 3-6 meters, relative to known benchmarks in the 80 square mile coverage area. Galaxy specifies overall system accuracy as 10 meters or better.

### In-Building Penetration

Galaxy reports that the P/L system can be configured to transmit at somewhat higher frequencies which tests indicate result in better in-building penetration. The level of power transmission from the towers impacts the ability of the system to compute location indoors.

### Cost

Galaxy reports that a network consisting of four towers and a System Area Monitor can be deployed at a cost of approximately \$200,000.

P/L receivers based on a single printed circuit board using standard components would be priced at approximately \$500. Incorporating a portion of the circuitry on an ASIC would reduce the price to about \$100. Galaxy indicates that with the volume that could be generated from integration of the P/L receiver into wireless phones, a P/L receiver in the form of a chipset would be forecasted to sell in the \$15-\$25 range. ✓

## Automatic Vehicle Monitoring Systems

In the 1970's, the Federal Communications Commission (FCC) established interim rules under which licenses to operate in the 902-928 MHz frequency band would be granted to companies for the operation of vehicle tracking systems in metropolitan areas. This band is shared with other licensed and unlicensed users. This band is referred to as the ISM (Industrial, Scientific, Medical) band or as the AVM (Automatic Vehicle Monitoring) band.

Several companies have obtained FCC license approval to operate vehicle tracking systems in this band, including the following:

- AirTouch Teletrac, Garden Grove, CA
- Pinpoint Communications, Inc., Dallas, TX
- Southwestern Bell Mobile Systems, Dallas, TX
- MobileVision, Boca Raton, FL

AVM-band systems have a number of common characteristics. All systems are based on a proprietary network of transmitting and receiving antennas deployed in and around a metropolitan area. In-vehicle transceivers, when activated by the pushing of an emergency button or other means, transmit a spread-spectrum code burst which is received by network antennas. Location is computed at a network control center based on Time-Difference-of-Arrival (TDOA) measurements. AVM-band systems offer data messaging in addition to vehicle location. One system, MobileVision, provides for voice communication as well as data.

For mobile 9-1-1 applications, an AVM-band transceiver could be interfaced to a wireless phone and programmed to have the unit automatically transmit when 9-1-1 is called. Location, computed at the AVM control center, along with caller identification, would be forwarded to the responsible PSAP. Interim FCC rules at this time generally limit the use of AVM systems to vehicular applications.

AVM-band systems typically cost several million dollars to deploy in a metropolitan area. The only company offering commercial services at this time is AirTouch Teletrac which has operational networks in six cities. Some other companies plan to deploy commercial networks in major cities in the near future.

The FCC is in the process of writing final rules covering AVM-band systems, which are expected to be issued this year.

Limited specific information on the Teletrac, Pinpoint and MobileVision systems follows. Southwestern Bell Mobile Systems reported that the company is not yet ready to provide details concerning its AVM system or deployment plans.

**AirTouch Teletrac**  
7391 Lincoln Way  
Garden Grove, CA 92641-1428  
Telephone: (714) 897-0877  
Fax: (714) 892-8637

### Background and Status

AirTouch Teletrac, formerly known as PacTel Teletrac, has been commercially operational since 1990. Teletrac provides stolen vehicle location and roadside assistance services for consumer applications and also provides vehicle location and data communication services for metropolitan area fleets. Teletrac reports that nearly 1,000 fleets subscribe to its Fleet Director service, making it the largest U.S. supplier of vehicle location for metropolitan area fleets. Teletrac is currently operational in Los Angeles, Chicago, Detroit, Miami, Dallas and Houston. The company has not reported any specific plans to deploy the network in other cities at this time.

Teletrac is 51% owned by AirTouch Communications, Inc.

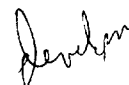
### System Accuracy

Typical accuracy of the Teletrac system is 100-150 ft. ✓

### Cost

The price of Teletrac transceivers is currently around \$300. The company reports that in large volume, the next generation transceiver could be priced at \$100 or less. The company reports that low cost transceivers could be embedded inside wireless phones, FCC regulations permitting.

Consumer stolen vehicle recovery and roadside assistance services are currently priced at approximately \$12-\$18 per month, depending on the service plan.



## **Pinpoint Communications, Inc.**

**Park Central VII  
12750 Merit Drive  
Suite 800, L.B. 20  
Dallas, TX 75251  
Telephone: (214) 789-8900  
Fax: (214) 789-8989**

### **Background and Status**

Pinpoint Communications, Inc. has developed the Array™ network which the company describes as an urban-based wireless data network which integrates high speed data communications with vehicle location. A series of field demonstrations of the system were conducted in the Washington, D.C. area in 1993. The company plans to conduct a six-month commercial test program in Dallas, Texas, beginning in early 1995. Pinpoint is attempting to raise funds to deploy the Array network in 40-50 largest U.S. metropolitan areas.

Pinpoint plans to commercialize the use of the Array network through alliances with applications enablers, systems integrators, value-added resellers, providers of user solutions and equipment manufacturers. Targeted applications include emergency notification, fleet management, vehicle security and other IVHS-related services for consumers.

### **Accuracy**

Pinpoint reports that location accuracy is 20-300 ft., with typical accuracy of 50 ft. or better. The system achieves this accuracy through a patented technique for measuring Time-Difference-of-Arrival, very accurate synchronization of base station clocks and a dense base station infrastructure.

### **Cost**

Pinpoint reports a target price of \$300 or less for vehicle-mounted transceivers. ✓

**MobileVision**  
1225 Broken Sound Parkway NW  
Suite E  
Boca Raton, FL 33487  
Telephone: (407) 241-7375  
Fax: (407) 241-7366

**Background and Status**

MobileVision was originally a joint development of METS and Ameritech. In 1992, METS took over development of the MobileVision system.

MobileVision, like other AVM-band systems, provides for vehicle location and data messaging. The system also provides for voice communications.

METS plans to deploy the MobileVision system initially in Chicago, Washington, D.C., Dallas and Los Angeles. Roll-out into these cities is contingent upon receipt of financing.

Targeted applications for MobileVision include fleet management, emergency notification, stolen vehicle recovery and other IVHS services.

Projected hardware and service cost information was not provided.

## OBSERVATIONS AND CONCLUSIONS

- Based on this survey, it is clear that the technology exists to locate callers using wireless phones to request 9-1-1 emergency assistance. Effective location systems based on either an overlay to the wireless network or external radiolocation networks can be operational in the next 12-24 months if location system developers, wireless network operators and phone manufacturers are motivated to implement these systems.
- A number of companies have developed location systems based on an overlay to an existing wireless network. Most of these systems do not require a modification or add-on to the mobile phone and, therefore, could automatically locate callers using existing cellular phones. ✓
- The best accuracy achievable with network-based location systems appears to be on the order of 100-300 ft., with degraded accuracy in dense urban environments. Most network-based systems do not work well indoors, as the strength of the transmitted signals used to compute location is reduced as the signals pass through the building's structure. Some suppliers plan to offer a handheld direction finding device to enable a responder to determine the exact location of the phone. ✓
- The cost of network-based systems ranges from under \$10,000 per base station to \$30,000-\$40,000 per base station or more. The deployment cost for a metropolitan area will typically range from under \$1 million to \$5 million or more. Generally, higher cost systems claim a higher level of accuracy.
- Several suppliers offer systems capable of locating 9-1-1 callers which use signals from existing networks without requiring an investment in infrastructure or network overlays. These systems are based on the Global Positioning System (GPS), signals from commercial FM radio stations or currently available cellular transmissions. Some of these systems will reportedly add little or no cost to a basic wireless phone. These systems offer varying degrees of accuracy and in-building penetration. ✓  
*interview  
state bank or partner  
of FM stations*
- Mobile 9-1-1 systems based on GPS are currently in the form of external receivers interfaced to a mobile phone. In the future, some suppliers expect to have GPS receivers embedded in the phone. Industry sources project that if a high percentage of cellular phones were equipped with GPS, the price of GPS receivers would be reduced to a few dollars per phone. GPS generally provides position accuracy of 100 meters or better, but GPS signal shadowing can occur in dense urban environments and the signals are not available indoors. On the whole, GPS is well suited for in-vehicle 9-1-1 location, but it would need to be used in combination with other technologies to cover in-building emergency calls from portable cellular or PCS phones. ✓

- Many of the systems which have been developed provide for location of a mobile caller, but not for passing location data and caller ID (ANI) through to the PSAP in a format compatible with existing PSAPs. Integration of wireless 9-1-1 location data into the PSAP in a standard format is a significant issue which should be dealt with in parallel with any implementation of location systems. ✓



## NETWORK-BASED LOCATION SYSTEMS

This section covers location systems which utilize the wireless communication network to compute the location of a mobile caller. Most systems covered require a modification to the network. Some systems require a modification to the phone. Systems developed (or in development) by the following companies are covered:

- KSI, Inc.
- Associated Communications Corporation
- Engineering Research Associates (E-Systems)
- TrackMobile
- U.S. West New Vector Group, Inc.
- Lockheed Sanders, Inc.
- Lattice Communications, Inc.
- Cartesia Corporation

Several other companies have technologies which could be enhanced to provide the capability to locate a 9-1-1 caller using a wireless network. Some of these technologies would require an overlay to the existing wireless network. A brief description of the location technology as it would be applied to locating mobile callers is included for the following companies:

- Qualcomm (CDMA)
- TRW (ESL)
- ArrayComm
- OAR Corporation
- Scientific Research Laboratories, Inc.

**KSI, Inc.**  
7630 Little River Turnpike, #212  
Annandale, VA 22003  
Telephone: (703) 941-5749  
Fax: (703) 941-5786

### Company Background

KSI, Inc. is a small, privately-held company which was formed in 1986. The company has provided analytical, systems and software engineering support to the government and to commercial clients. In addition to the development of cellular location technology, KSI has designed and integrated sonar systems for the U.S. Navy and has also supported the Navy in the areas of advanced signal processing; detection, localization and tracking; analysis of acoustic and RF signal sources; tradeoff studies and parametric analyses; and data fusion and artificial intelligence.

### Direction Finding Localization System

KSI began development of its Direction Finding Localization system (DFLS) in 1989. The system was designed to compute the location, speed and heading of users of wireless phones. A prototype DFLS has been operational since 1991.

The DFLS system requires the installation of directionally sensitive receiving antennas, called Sensor Stations (SSs) which may be collocated at the wireless network antenna sites. SSs capture transmitted (control or voice) signals from wireless phones and process these signals to determine the angle of arrival. The directional information from the SS is relayed via a wired or wireless data link to a Central Station (CS) which processes the received data and computes the location of the caller. For 9-1-1 applications, DFLS can provide the caller's phone number and location to a Public Safety Answering Point (PSAP).

For 9-1-1 applications, DFLS can reportedly compute the caller's location in milliseconds before voice communication begins. KSI reports that the system is capable of computing the location of as many 9-1-1 callers as can access the communication network. The company reports that the system is compatible with wireless networks such as cellular, PCS and ESMR. The DFLS system was patented in 1988.

### Target Applications

Intended applications for DFLS include emergency notification (9-1-1), roadside assistance, routing, and fleet management. The system can be used to gather probe information for traffic monitoring in support of IVHS Advanced Traffic Management Systems.

### System Status

A demonstration DFSL system consisting of two SS units and one CS has been operational in the Annandale, Virginia, area since 1991. The company reports that a significant amount of field testing has been done tracking a company control group as well as thousands of targets of opportunity.

KSI reports that the DFSL system could be commercially deployed within one year, if sufficient funding is available.

### Wireless Phone

DFSL does not require any modification to the wireless phone. Once deployed, the system will compute location of existing cellular phones as well as phones operated on future cellular and PCS networks.

### System Accuracy

KSI claims typical location accuracy of 150 feet. This accuracy is based on the system's capability to compute bearing to the SS with an accuracy of 0.3 degrees. Accuracy achieved is impacted by the proximity of the phone to SS receivers, noise and the multipath environment. A higher level of accuracy can be obtained with bearing measurements from more than two sites.

### Performance in Dense Urban Environments

Accuracy in dense urban environments may be degraded due to increased effects of multipath. Performance in dense urban environments can be improved through installation of additional SS units, which need not be located at network antenna sites.

### In-Building Penetration and Vertical Resolution

DFSL will provide only limited in-building penetration due to the signal strength reduction caused by the structure. If a micro-cell is located in a building to support wireless communications within the building, the KSI system will identify the building from which the call was placed and, based on measurements from the microcell, may be able to determine from which floor a call was placed.

### Projected Cost of Deployment

KSI estimates the cost of deployment for a basic system at approximately \$30,000 per SS, including one CS, which can generally cover a metropolitan area. The estimated cost to deploy DFLS on a wireless network in a major metropolitan area is \$3-5 million.

KSI is currently developing an Enhanced Direction Finding System (EDFS) which could be deployed at a cost of under \$30,000 per SS, depending on capabilities required, system complexity and the number of network sites.

## **Associated Communications Corporation**

3 Bala Plaza East, Suite 502  
Bala Cynwyd, PA 19004  
Telephone: (610) 660-4910  
Fax: (610) 660-4920

### **Company Background**

Associated Communications Corporation commenced operations in November, 1979. The company has holdings in a number of communications companies and also actively operates communications businesses. Associated owns and operates cellular and microwave systems and has significant holdings in cable TV networks. The company is the majority owner of cellular networks in Buffalo, Rochester and Albany, New York and other locations. Associated has entered into a definitive merger agreement with Southwestern Bell with regard to these cellular properties which is expected to lead to the sale of these holdings later this year. The company owns 30% interest in Portatel del Sureste, S.A. de C.V., which provides cellular telephone service in five Mexican states. Associated, through a joint venture, has experimental licenses from the FCC to test Personal Communications Services technology in Los Angeles and Washington, D.C. and has purchased interest in an entity pursuing PCS licenses. Associated Communications Corporation is listed on the NASDAQ stock exchange.

Associated began development of its Cellular Location System in early 1992. The company currently has a staff of engineers (internal staff and consultants) dedicated to development and testing of the system.

### **Cellular Location System**

Associated Communication Corporation's Cellular Location system computes the location, speed and heading of callers using wireless phones. The system is based on Time-Difference-of-Arrival (TDOA) measurements made on the reverse control channel transmissions from phone to cell site.

The Cellular Location System requires that equipment be installed at "coverage" cell sites, but not at "capacity" cell sites. (Capacity sites are sites that have been added to cover increases in network usage.) In a major city, typically about 2/3 of today's cellular network cell sites are "coverage" sites. Equipment installed at these sites includes an omnidirectional antenna (unless one is already in use) and a dedicated receiver which has a wider bandwidth, better timing and higher sensitivity than the cellular network receiver. To compute location the receiver measures the time of arrival of the center of energy (otherwise known as Group Delay) of the 100 millisecond control channel transmission. The data from the cell sites is passed to a digital signal processing system at a Central Site (typically at the MTSO) which computes location based on the intersection of isodelay

curves generated from the TDOA measurements. The caller's location is computed in real time after receipt of control channel transmissions.

On July 5, 1994, U.S. Patent #5,327,144 covering the Cellular Location System was issued to Associated RT, Inc., a subsidiary of Associated Communications Corporation.

### Target Applications

Intended applications for the Cellular Location System include emergency notification (9-1-1) as well as a wide range of consumer and commercial fleet applications.

### System Status

Associated's Cellular Location System was demonstrated over a six month period (late 1993/early 1994) in the Rochester, New York area, using the company's local cellular network. Demonstrations were conducted for other cellular operating companies and for national organizations seeking to market location-dependent services. Limited field testing was also done at that time, but test data has not been published.

Associated Communications estimates that in 18-24 months the location system can be commercially deployed and integrated into existing 9-1-1 operations. The company is actively pursuing partnerships and alliances to commercialize the location technology and to participate in further technology enhancement and development.

### Wireless Phone

The Associated Communications system does not require any modification to cellular or other wireless phones. Once deployed the system will compute the location of existing users of the network as well as new users.

### System Accuracy

Associated Communications claims typical system accuracy of 500 ft. RMS, under a variety of conditions, with its prototype Cellular Location System.

Accuracy in dense urban environments may be degraded due to multipath. However, some of the impact of multipath is offset by the fact that dense urban areas usually have more cell sites, making it possible obtain a more redundant solution.

**TrackMobile, Inc.**  
550 West B Street, Suite 250  
San Diego, CA 92101-3537  
Telephone: (619) 235-6085  
Fax: (619) 235-0213

### Company Background

TrackMobile, Inc. was incorporated in 1989 for the purpose of providing location-dependent services for consumer and commercial applications using the cellular network. TrackMobile services will be marketed under the name Help Express. To date, the company has focused primarily on developing technology, service specifications and business alliances. TrackMobile plans to commence commercial operations in a major city in the 1st quarter of 1995.

TrackMobile currently has under 10 employees and plans to expand its staff to 30 in the 1st quarter of 1995. Allstate Insurance company is a major investor in TrackMobile and the primary source of funding to date.

### Cellular Location Technology

TrackMobile has developed location technology which uses existing cellular, PCS or SMR networks. The system is designed to compute location on either analog or digital networks. No modification to the network is required.

TrackMobile cellular phones are marketed under the name "Helpfon". The software in the phone is modified to transmit signal strength measurements of control channels from each cell site, including both A and B side cellular operators. The range to three or more cell sites is computed based on the signal-to-noise ratio of the received signals. The available signal strength is passed through the network to the Help Express Service Center where the caller's location is computed by triangulation. Speed and heading are also computed. TrackMobile holds several U.S. patents on its location technology.

Emergency messages transmitted from a Helpfon are received at the Help Express Service Center, which is housed at the National Dispatch Center in San Diego, CA. The nature of the emergency along with the identification and location of the caller are received by the TrackMobile dispatcher. Calls requiring 9-1-1 response are passed to one or more responsible 9-1-1 jurisdictions, based on the caller's location. TrackMobile field response team members (off-duty police officers) use portable direction finding devices to determine the exact location of the caller, in support of the responding law enforcement agency.

The TrackMobile system is designed to work with wireless networks including cellular, PCS and ESMR.

### Target Applications

Intended applications for the TrackMobile Help Express service include location enhanced 9-1-1 response, stolen vehicle recovery, medical emergency response, roadside assistance, personal security response and street and address finding.

### System Status

TrackMobile reports that work on the technology commenced in 1989. In the past 3 years over 400 field tests of the system have been conducted. It was reported that 75 audited field and product tests have been conducted by cellular phone manufacturers and cellular carriers.

The management of TrackMobile reported that the company is negotiating with a cellular operator for an ownership position in TrackMobile. The company also reported that it is close to closing a deal with a major cellular phone manufacturer to produce HelpFons which incorporate special software to support location.

TrackMobile plans to launch the Help Express service in a major U.S. city in the 1st quarter of 1995. The company plans to offer services in 30-50 of the largest MSA's within five years.

### System Accuracy

TrackMobile reported that typical location accuracy is 500 feet. A reduced level of accuracy is obtained in marginal cellular coverage areas. A radio direction finding device, with a range of approximately two miles, is used to locate the precise location of the caller.

### Performance in Dense Urban Environments

TrackMobile reports that it has done extensive algorithm development and testing to deal with multipath in urban environments. Averaging techniques are used to obtain the best possible accuracy in the operational environment.

### In-Building Penetration and Vertical Resolution

The company reports that if a call is placed from inside a building, at a minimum the cell from which the call was placed is identified. The precise location of the caller, including the floor on which the caller is located, can be identified using the radio direction finding device.



### Projected Cost

TrackMobile reports that the cost of a HelpFon will not be any greater than the cost of a standard cellular phone. Both mobile and portable phone configurations will be available, priced around \$200.

## **U.S. West New Vector Group**

3350 161st Avenue S.E.  
Bellevue, WA 98008  
Telephone: (206) 562-5060  
Fax: (206) 562-5640

### **Company Background**

U.S. West New Vector Group, Inc. is a wholly-owned subsidiary of U.S. West, Inc. U.S. West New Vector Group owns and operates cellular networks in a number of cities including Seattle, Phoenix, Denver, Minneapolis and San Diego. Annual revenues of U.S. West, Inc. exceed \$10 billion.

U.S. West New Vector has been researching position determination technologies since 1991. The company has focused on development of systems which could address broad consumer markets and which would have a minimal impact on handset and network costs. The company reports that it has done development work on relatively coarse systems that define location as relatively large zones and also on highly accurate systems. For the past 9 months, New Vector has been conducting active technical research on a relatively high accuracy, low cost system suitable for a broad range of applications.

### **Cellular Location Technology**

The location system being developed by New Vector uses Time-of-Arrival multilateration techniques to locate a caller. The system can operate in the cellular, ESMR or PCS bands. The system requires the installation of special equipment at more than 50% of the network cell sites. A modification to the wireless phone is also required, which will most likely consist of one integrated circuit and software. The IC can be embedded in a standard AMPs phone or a dual mode digital phone. The system is designed to compute location in the phone, though the system is also capable of computing location in the network. U.S. West has applied for a patent on the specific technique used to compute location.

### **Target Applications**

Intended applications for the New Vector location technology include fleet management, emergency location services, fraud detection services, property tracking and recovery services and personal safety/security services.

### **System Status**

U.S. West New Vector reports that extensive analysis and simulation of the system has shown that theoretical accuracy of 100 ft. is probable.

A field test program commenced this month (July, 1994) to address performance in stationary outdoor environments, indoor environments including high rise buildings and moving vehicle tests. New Vector reports that the system is being tested in the presence of moderate and severe multipath and GDOP (geometry of equipped cell sites). Wide area testing will be conducted. Field testing will continue through August, 1994.

U.S. West New Vector states that it will be willing to share details of its research and systems development with interested government agencies under non-disclosure beginning in September, 1994. The company reports that it is premature to estimate when the system will be available for commercial deployment.

### System Accuracy

New Vector reports that empirical data on system accuracy will not be available until field test results are processed.

### Cost

Based on the technology used, it is projected that the cost of the chip to be embedded in the phone will be approximately \$3. Based on available data regarding the New Vector system, it is estimated that the cost of the network equipment will be approximately \$1/2 million each for cities such as the primary U.S. West cellular markets.

### In-Building Penetration and Vertical Resolution

New Vector reports that the location system is designed to provide maximum in-building penetration. In the New Vector system, transmission from cell sites will be at the legal limit of 500 watts ERP. The company claims that this provides a 20dB advantage over systems which rely on .6 watt transmission from a portable wireless phone. Field test data will be obtained in shopping malls, high rise buildings and other indoor locations.

New Vector has not conducted any tests to determine the capability of the system to resolve altitude.

**Lockheed Sanders, Inc.**  
65 Spit Brook Road  
M/S PTP02-C002  
P.O. Box 868  
Nashua, NH 03061-0868  
Telephone: (603) 885-8055  
Fax: (603) 885-8685

### Company Background

Lockheed Sanders, Inc. is engaged in the development, manufacture and sale of advanced electronic systems and products in a broad range of markets. Major business areas include signals intelligence and communications jamming systems, information display systems, automated test systems and RF, microwave, millimeter wave, optical and acoustic systems. The company reports that it has some 40 years of transmitter location experience.

Lockheed Sanders, Inc. has approximately 4,500 employees. It is a wholly owned subsidiary of the Lockheed Corporation.

### Cellular Location Systems

Lockheed Sanders, Inc. reports that it is developing a product line of equipment for determining the precise location of cellular phones in high multipath, urban environments. The network equipment consists of a receiver and processor contained within a standard chassis. The unit is designed to either stand alone or to interconnect to existing network equipment. A proprietary Time-Difference-of-Arrival (TDOA) technique is used to compute the approximate location of the caller.

The product line being developed includes a handheld device for use within buildings and at close range, which employs a proprietary direction finding technique.

### Target Markets

Applications for the Lockheed Sanders system include mobile Enhanced 9-1-1, combating fraudulent cell phone use, fleet management, personal safety, location-based yellow pages and other location-dependent commercial and consumer services.

### System Status

A prototype of the cellular location system has been developed. Field tests conducted to date have been on the company's proprietary base stations and not on an operational

cellular network. Lockheed Sanders reports that they are working on establishing relationships with cellular carriers. The company states that the system will be ready for customer field trial deployment by the end of 1994 and for commercial deployment in 1995.

#### Accuracy

Lockheed Sanders states that the accuracy of the cellular location system is currently under field testing and verification. They report that the handheld unit determines a cellular phone's location without any residual ambiguity.

#### In-Building Penetration and Vertical Resolution

Lockheed Sanders reports that the use of the handheld direction finding device will enable 9-1-1 responders to identify the location of the phone inside a building. The determination of the floor on which the phone is located is planned as a future growth option.

#### Cost

The company states that is not in a position to disclose cellular location cost estimates at this time.

## **Lattice Communications**

14205 SE 36th St., Suite 100

Bellevue, WA 98006

Telephone: (206) 649-1141

Fax: (206) 649-1199

### **Company Background**

Lattice Communications was founded in 1993 for the purpose of developing a system for identifying the location of the caller using a wireless network. The founders of Lattice have business and technical experience in such fields as cellular communications, satellite communications, radar, and real time wide area networks. They have reportedly made technical contributions to companies such as Motorola, Cubic Defense Systems, TRW, PacTel Corporation and U.S. West.

Paul Norris, President and CEO of Lattice Corporation, co-founded two successful high-tech companies in the 1980's. One these companies, Quantum Medical Systems, developed medical diagnostic products and was sold to Siemens AG. Quantum Medical systems currently employs some 400 people. Norris also founded Seattle Silicon, now called Cascade Design Automation, which developed customer integrated circuit design technology and was sold to Oki Electric. Cascade's silicon and gallium arsenide design tools are currently used by Oki and other major communications equipment suppliers.

### **Location Technology**

The location technology being developed by Lattice Corporation consists of an overlay to the wireless network. No modification to the phone will be required. Lattice reports that a key element of the system design is its ability to mitigate the effects of multipath propagation. The company does not wish to discuss the technique used to compute location in greater detail at this time except under non-disclosure. Lattice Communications holds U.S. patents on some of the techniques used in its system.

### **Target Applications**

Intended applications for the Lattice system include 9-1-1 emergency notification, fraud interdiction, and other location-dependent commercial and consumer applications.

### **System Accuracy**

Accuracy of the Lattice system is site and installation dependent. The company's investigations to date indicate that approximately 95% of measurements will be within a window of 300 ft. or less.

### System Status

Lattice Communications estimates that the location system will be available for commercial deployment in 1996. The company will be seeking alliances with wireless operators in order to fund commercial deployment.

### Performance in Dense Urban Environments

Lattice reports that the system is designed to operate in all wireless operating environments where communications are possible. Accuracy is somewhat degraded in dense urban environments.

### In-Building Penetration and Vertical Resolution

Lattice states that the system's in-building penetration will be comparable to the wireless frequency being used. The company claims that a unique feature of its technology is that it will provide a measure of vertical resolution, depending on the environment and proximity to the base stations. Vertical resolution will be limited, however, due to typically unfavorable geometric conditions of a base stations located in a horizontal plane.

### Projected Cost of Deployment

The cost to deploy the Lattice system will vary depending on the network equipment configuration at the cell site. Lattice feels it is premature to publicly discuss deployment costs, other than to say that system is designed to be relatively low cost.

## **Cartesia Corporation**

**3100 McKinnon  
Suite 900 - LB 126  
Dallas, TX 75201  
Telephone: (214) 954-0022  
Fax: (214) 871-1591**

### **Company Background**

**Cartesia Corporation is a privately-held company which was formed in 1992. The company was formed for the purpose of applying advanced digital communications software and mapping technology to the needs of public agencies. The company's products are targeted at municipal and state agencies, law enforcement organizations and emergency service providers. The company's principal products are software packages which support the design of Emergency Service Network (ESN) boundaries, the maintenance of 9-1-1 Master Street Address Guide files and the mapping of 911 calls as they are received by calltakers.**

**In January, 1994, Trident Tracking Technology, Inc., which had been formed to develop cellular-based location technology, approached Cartesia Corporation with some preliminary software for computing the location of radiating sources using triangulation. Cartesia spent the next several months further developing the algorithms and integrating the location technology with the company's conventional PSAP mapped-ALI screen. In June, 1994, Cartesia Corporation entered into negotiations to acquire Trident Tracking Technology, Inc. The merger of the two companies is expected to be completed before the end of 1994.**

**Cartesia Corporation currently has 7 employees. The company is in the process of acquiring a 9-1-1 consulting company, which will increase the company's staff to approximately 20.**

### **Cellular Location Technology**

**The Cartesia location system computes the location, speed and heading of callers using an overlay to the wireless network. The system tracks the control channel transmissions from the phone at 3 or more cell sites to compute the user's location.**

**Cartesia's location system hardware is installed at each network cell site. Data from each cell site is passed to the system processor located at the switch (MTSO), where the location of the caller is computed. The company's management declined to provide details concerning the equipment installed at the cell sites and the technique used to compute location. Cartesia Corporation has not yet filed for patents on the system.**



The Cartesia system does not require any modification to the phone. The system is compatible with a wide range of wireless networks, including cellular, PCS and ESMR.

### Target Applications

The Cartesia location system has been developed primarily to support E9-1-1 applications over wireless networks. Cartesia Corporation also intends to apply the technology for other commercial and consumer applications through alliances with wireless network operators. Intended applications include passive devices for tracking children, fleet vehicle location, monitoring the location of high value assets and cellular fraud detection.

### System Status

In early 1994, Cartesia Corporation conducted a simulated test of a large number of 9-1-1 calls, based on cellular tower locations in Tarrant County, Texas. The company reported very positive simulation results.

Field testing of the Cartesia location system will commence this summer. Cartesia is negotiating with local cellular carriers to provide facilities for the testing. Cartesia reports that a local 9-1-1 district has received a public grant to conduct tests of wireless network caller location. Cartesia plans to provide test results in support of the work being done under this grant.

Cartesia's management stated that they expect to make an announcement in the 4th quarter of 1994 that the location system is ready for commercial deployment. The company plans to form alliances with cellular operating companies who will support deployment of the system.

### System Accuracy

In field tests scheduled for the second half of 1994, Cartesia Corporation expects to demonstrate static test results of 70 ft. or better. (However, no field data has been obtained to date to confirm this level of accuracy.) System latency of approximately 5 seconds is anticipated in computing location, which will not affect static accuracy, but may impact dynamic performance.

### Urban and In-Building Performance

Field tests will determine the accuracy obtainable in dense urban environments and inside buildings. Cartesia believes its system will handle multipath more effectively than most competing systems.